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Impact of an emissions trading scheme on Australian households: A computable general equilibrium analysis

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ABSTRACT

Following the international commitment to tackle climate change issues, many countries have introduced climate change policies to reduce emission levels. Australia also expects to follow the international pathways to implement a climate change policy to curb its greenhouse gas emissions. In this context, the former Labor Government in Australia intended to switch its carbon tax policy to an emissions trading scheme (ETS) after 2 years of its initial operation to achieve an emission target of 5 per cent below the 2000 level by 2020. By employing a computable general equilibrium model and a social accounting matrix database, this article analyses the potential impacts of an ETS with various revenue recycling options on Australian households. Results show that an emission permit price of A$20 per tonne of CO2-e would help Australia to achieve the 2020 emission reduction target. This permit price is likely to have a small contraction in Australia's real GDP (i.e. about 0.3 per cent) and in real household consumption (i.e. about 0.19 per cent). The price of electricity is projected to increase by 13 per cent. The revenue recycling options seem to create an improvement in the macro-economy and there is a trade-off between economic efficiency and equity in the Australian economy with compensations. The personal income tax reduction policy results in an economic efficiency with a positive change in real aggregate household consumption whereas providing an equal lump-sum transfer brings benefits equally for all household groups. Increased government transfers based on recipients' current pension and allowance rates generate more welfare gains for middle-income household groups.

1. Introduction

The impact of global warming has been recognised across the globe. The Intergovernmental Panel on Climate Change (IPCC, 2014) stated that global surface temperatures have increased by an average of 0.85 °C over the period 1880 to 2012. This report also claimed that anthropogenic greenhouse gas (GHG) emissions, mainly carbon dioxide (CO_2), stemming from fossil fuel combustion, have been a substantial contributor to the surface temperature increase since the mid-20th century. In recent years, evidence of climate change has been observed in Australia. The Climate Change Authority (2014) reported that the average surface air temperature has increased by 0.9 °C since 1910. According to Arndt et al. (2015), Australia had the warmest year in 2013, while 2014 was the third warmest year since the recording of national temperature which began in 1910. This is mainly due to GHG emissions generated from energy production and consumption. Australia was the world's ninth largest energy producer in 2017, accounting for 2.74 per cent of the world's energy production and coal is Australia's main energy production (72 per cent) as well as a main source to produce electricity (World Energy Statistics, 2018). It is reported that Australia was responsible for 1.14 per cent of the world's GHGs emissions in 2016 which made the country the 16th highest overall GHG emissions contributor (Ritchie and Roser, 2017).

Over the last decade the consecutive Australian Governments have debated which policy is the best to reduce emissions in the light of its international commitments. For instance, in 2009 at the Copenhagen conference on climate change, the Australian Government committed unconditionally to reduce the country's emissions by 5 per cent below the 2000 level by 2020, and

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conditionally to mitigate by up to 15–25 per cent below the 2000 level by 2020 (Nong and Siriwardana, 2017). To achieve the emission reduction target, the then Labor Government implemented the carbon pricing mechanism with two periods in the process: a fixed carbon price in the first three-year period from 1 July 2012 with an initial price of A$23/t$CO_2$-e and a floating carbon price period from 1 July 2015 (Siriwardana and Nong, 2018). However, the subsequent Liberal/National Coalition Government abolished the carbon pricing mechanism and replaced it with a Direct Action Plan (DAP) from July 2014 (Nong and Siriwardana, 2018a; Simshauser and Tiernan, 2018). Some commentators judged the DAP to be costly to taxpayers and ineffective in fighting climate change, and achieving the emission reduction target at a higher cost than the operation of a carbon price (Grudnoff, 2011). Placing a price on emissions is a cost-effective approach to reduce emissions (Stern et al., 2006; Garnaut, 2011). In Australia, the carbon pricing policy contributed to a reduction of between 5 and 8 million tonnes of CO_2 emissions in 2012/13 and between 6 and 9 million tonnes of CO_2 in 2013/14, and together between 11 and 17 million tonnes in the two years of the operation of the carbon pricing policy (O'Gorman and Jotzo, 2014).

Moreover, a carbon pricing policy such as a carbon tax or an emissions trading scheme (ETS) can raise considerable revenue for a government. An appropriate use of these revenues to cut distortionary taxes can lead to a 'double dividend', including an improvement in the environmental quality and economic efficiency (Tiezzi, 2005; Orlov et al., 2013). The Australian Treasury estimated that the carbon pricing mechanism would increase household expenditure by A$9.90 per week; of this increase, A$3.30 was attributed to electricity consumption, A$1.50 to gas consumption, A$0.80 to food consumption, and the remaining A$4.30 to the consumption of other goods and services (The Treasury, 2011). The Household Assistance Package that accompanied the carbon pricing policy was assessed to be higher than the average carbon price impact for low-income households and 60 per cent to 95 per cent of the carbon price impact for middle-income households (Hatfield-Dodds et al., 2011). The impacts of the revenue recycling policy depended on how the Government used the revenue raised from the carbon tax or auctions to compensate affected populations.

The primary purpose of this paper is to examine the impact of an ETS on the Australian economy, mainly focusing on Australian households under three revenue recycling options: (1) reductions in personal income taxes based on their current income tax levels (Scenario INT), (2) increases in government transfers based on recipients' current pension and allowance rates (Scenario GOV), and (3) a provision of an equal lump-sum transfer for all household groups (Scenario ELS). In this context, the ETS is designed to help Australia to achieve the emissions target of 5 per cent below the 2000 level by 2020. The implementation of climate change policies and their likely impacts have been hotly debated in Australia for decades. However, there have been no studies that explicitly examined the impacts of such policies on many different groups of households. Since households are highly vulnerable to such a taxing policy, a study focusing on multiple groups of households are extremely desirable and timely. There are some methods used for recycling the tax revenue: use the revenue to subsidise renewable technology and investment, to support highly unfavourably-affected industries, to support households and so on. Different recycling approaches may yield different impacts on industries and households. If revenues are not directly recycled to households but to industries, households may benefit from reduced prices and increased demands for labour. However, direct transfers to households would considerably help vulnerable households to increase their budgets because such transfers allow them to freely allocate budgets depending on their own interests and consumption preferences. Hence, examining the impacts of different approaches of recycling revenues within the context of highly disaggregated households can undoubtedly improve the knowledge of policy makers. In addition, social assistance benefits in cash to residents (i.e. pensions and allowances) account for around 30% of total government expenses in Australia as shown in the household expenditure survey 2009–10, hence recycling the ETS revenues based on these shares would be a good preference to design a supporting policy in Australia. Findings would encourage the international community to adopt such mechanisms in their own environment policy developments.

Potential impacts of ETSs have also been well studied in the literature (for example, see Kopsch (2012); Schwaiger et al. (2012); Lin and Jia (2017); Nong and Siriwardana (2018b); and Liu et al. (2018)). However, only a few studies examined the impacts of an ETS associated with various recycling options to compensate households in order to moderate the impacts of such a policy. In addition, no studies have been conducted to quantify the impacts of an ETS on a large number of household groups (i.e. 20 groups) as examined in this study. Such a new approach would make a significant contribution to the literature of climate change policy, which assesses the impacts on different household groups. Moreover, the production structure related to electricity generation from different sources would be valuable for climate change and energy economics modelling. That is, all generated electricity is first transmitted to the electricity distribution sector before reallocating it to the entire economy by using its distribution network. In many studies, generated electricity and electricity distribution commodities are aggregated. In addition, quantified impacts of different recycling options of ETS revenues are also extremely useful for policymakers to design effective and equitable carbon price policies.

The paper is organised as follows: Section 2 reviews studies that have used CGE models in analysing the effect of carbon pricing policies; Section 3 provides the information on modelling; a description of the database is presented in Section 4; and Section 5 examines the effects of the ETS under the three scenarios of revenue recycling. Main conclusions are given in Section 6.

2. Literature review

An ETS is a way of achieving an emissions reduction target with the least costs when the marginal abatement cost is equalised among firms. That is, all firms face the same emission permit price (Villoria-Saez et al., 2016; Nong et al., 2017). Under an ETS, the tradable permit system fixes the quantity of emissions generated in an economy and leaves the market to determine the price of permits, thus there is uncertainty about the emission abatement cost. Weitzman (1974) indicated that an ETS would be favoured when the marginal abatement cost is relatively stable. The effectiveness of an ETS depends on how a government allocates emission permits to polluting firms (Li and Jia, 2016); either through free allocation (grandfathering) or auctions. Previous studies show that the permit auction approach is preferable to free allocation in terms of both economic efficiency and distributional effects (Cramton and Kerr, 2002; Parry, 2002).

The effects of an ETS also depend on how the government uses the revenue raised from auctions to compensate vulnerable populations (Lin and Jia, 2018a). There is a trade-off between efficiency and equity in two forms of the revenue recycling, such as direct compensation policies (lump-sum transfers) and indirect compensation policies (a reduction in taxes) (Beznoska et al., 2012; Rausch et al., 2011). For instance, Rausch et al. (2011) applied a general equilibrium model with a detailed disaggregation of 15,588 households as individual agents to explore the distributional and welfare effects of a cap and trade system with fully auctioned

permits. They compared the impacts of three scenarios of revenue returned to households. With a permit price of US$20/t$CO_2$, results suggest that the revenue returned to lower personal income tax households would induce the lowest average cost of 0.18 per cent of household income, welfare costs would be the highest at 0.46 per cent if the revenue was recycled on a per capita basis. There is a trade-off between efficiency and equity when the policy of compensation for lower personal income tax households is most regressive, and per capita household rebate is progressive. In the case of British Columbia, Beck et al. (2015) found that a carbon tax would be highly progressive even prior to consideration of the revenue recycling scheme as such revenue recycling improved the situation further for the poor income group households. Liu and Lu (2015) examined the impacts of different carbon tax revenue recycling options in China. The authors found that the impacts of a carbon tax on households, social welfare, real GDP and industrial output levels would be significantly moderated when revenues raised from such a carbon tax were recycled to reduce either consumption tax or production tax.

Beznoska et al. (2012) examined the distributional and welfare effects of the European Union (EU) ETS, which was designed to achieve a 20 per cent of emission reduction below the 1990 levels by 2020. The emission price was assumed at €25 per permit. The effects on the prices of goods were classified for cases with and without accounting for behavioural response of consumers to price changes caused by the EU ETS. The effects were regressive in both cases. If revenue was used to provide a lump-sum rebate and reduce social security contribution, the results indicate that the effects would be progressive in the former and remained regressive in the latter. This is an example of trade-off between efficiency and equity in the two forms of the revenue recycling. Lin and Jia (2017; 2018b) also found that recycling revenues of an ETS would slightly increase social welfare.

In Australia, the former Labor Government implemented the carbon pricing policy with a fixed carbon price, with the plan to switch to a flexible carbon price. The purpose of this policy was to achieve the emissions reduction target in the light of the Kyoto Protocol commitment. Therefore, there have been some studies using CGE models to measure the effects of the carbon pricing policy on the Australian economy and households. With regard to carbon price, carbon tax policy was assessed to be regressive (Lin and Zia, 2018c; Renner, 2018). Meng et al. (2014) and concluded that the carbon tax is moderately regressive under the scenario without revenue recycling options, but it is progressive under the compensation scenario. Siriwardana et al. (2013) suggested that each household should receive an annual lump-sum payment of A$685 in the event of an implementation of A$23 per tonne carbon tax. The compensation policies to Australian households were also examined extensively by Sajeewani et al. (2015) and they stated that the revenue recycling option through reducing the personal income tax would support the double dividend hypothesis when it enables to reduce the distortionary income tax in the economy. Meanwhile the compensation option is more welfare improving when it is distributed equally across all household groups.

There are some earlier studies that employed CGE models to measure the effects of an ETS on the Australian economy. In particular, Adams (2007) evaluated the potential costs of an ETS for Australia by employing a CGE modelling approach integrating the Monash Multi-Regional Forecasting (MMRF) model and the McLennan, Magasanik and Associates (MMA) model. Electricity generators using fossil fuels received a free allocation of permits to compensate for losses in profit and trade-exposed emission-intensive industries were compensated for 100 per cent of increased energy costs. Limited banking of permits was allowed in the modelling. The permit price was estimated to increase from A$18.30/t$CO_2$-e in 2010 to A$50.20/tCO_2-e in 2030 in order to achieve the total emission rate of 21.1 per cent by 2030. The ETS resulted in decreased real GDP of 1.3 per cent and real consumption by 1.4 per cent relative to their baseline value in 2030. There was a reduction in output of coal-fired electricity, electricity distribution and air transport services industries, while the ETS significantly raised output of the renewable electricity industry.

Buddelmeyer et al. (2012) assessed the impact of climate change mitigation policy on income and inequality in Australia by linking the MMRF-Green model and a Micro-simulation model. The ETS was assumed to achieve an emission reduction target of 80–90 per cent below 2000 levels by 2050. The results showed that inequality would increase, while the revenue transfer to households had a positive impact on the lower income quintile and a negative impact on the higher income quintile. The lump-sum transfer would bring more benefits to the low-income quintile, thus playing an important role in reducing inequality. Nong et al. (2017) found that an ETS would only cause Australia to experience a decline of its real GDP by 0.85%. In addition, impacts on different household groups would be moderate since the government uses revenues raised from the implementation of an ETS to compensate households. The authors also found that the impacts of an ETS would be much greater of 2030 compared to the impacts in 2020 due to tightened emission targets. Meng et al. (2018) integrated a static CGE model with an electricity-detailed model to quantify the impacts on an ETS on various industrial sectors in Australia. This study found that an ETS would be an efficient instrument in Australia to reduce the emission levels with a small trade-off of contractions in the economy.

The literature review shows that an ETS has impacts on all aspects of an economy, and the revenue raised from auctions can be used to mitigate undesirable effects of an ETS with a trade-off between efficiency and equity. However, none of these studies showed the detailed impacts of an ETS on a large number of household groups as provided in this study. In addition, this study also examines the impacts of various recycling options, which are limited in the literature, to assist policymakers to design efficient and equitable climate change policies.

3. Model structure

A CGE model is a practical way of quantifying the effects of policies and other shocks on industries, occupations, regions, and socio-economic groups (Dixon and Jorgenson, 2013). The model used in this study is a static CGE model that is based on the ORANI-G model (Horridge, 2003). The ORANI-G model incorporates a system of equations that describe the behaviour of producers and consumers in an economy for a given time period. There are a number of assumptions in the model, for instance, agents are assumed to be price-takers (a perfect competition) and demand and supply equations for private sector agents are derived from the solutions to the optimisation problems (cost minimisation and profit maximisation for producers and utility maximisation for consumers). In comparison to the ORANI-G model, there are modifications in treating energy commodities in the structure of production of the current model. The model allows for substitution between energy inputs, between electricity types produced by different energy sources, and between capital and energy inputs.

The production structure consists of five levels of nested Leontief and the constant elasticities of substitution (CES) functions. Fig. 1a shows the production structure of the electricity distribution sector. At the top level, intermediate input bundles, energy-primary factor bundles and electricity composite are combined using a Leontief production function, implying that they are used in a fixed proportion to produce outputs. Such a structure was constructed because in Australia electricity generation from different sources

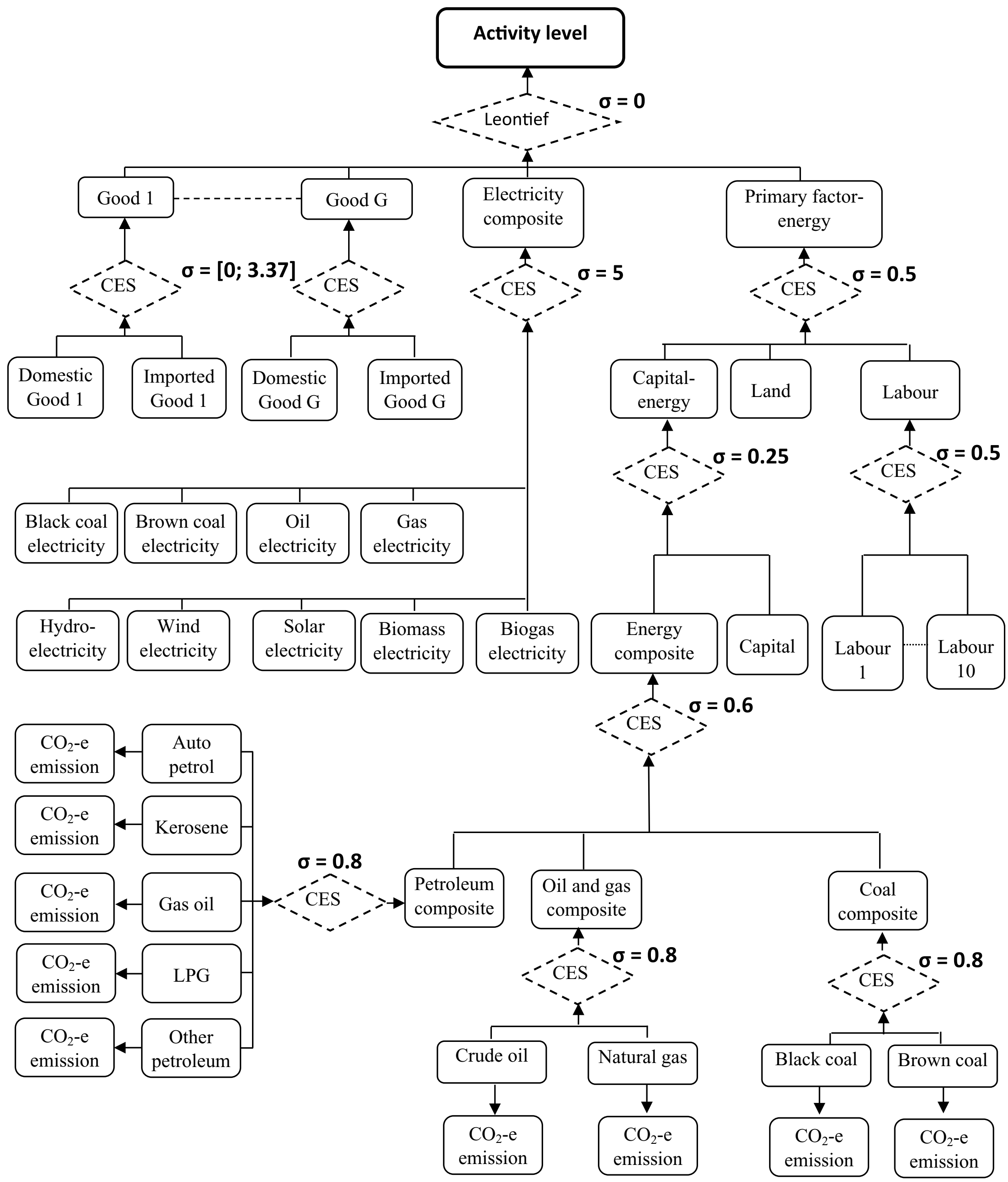

Fig. 1a. The production structure of the electricity distribution sector.

are collected by the electricity distribution services sector. This sector then adds their service fees through construction and maintenance of electricity distribution networks and sells electricity to other sectors. This electricity selling activity to other sectors is called 'commercial electricity' commodity as provided in Fig. 1b. In other words, the non-electricity distribution sectors only use 'commercial electricity' provided by the electricity distribution sector, i.e. the electricity is not provided directly from generating sectors. Apart from the block of electricity, production structures of the electricity distribution and non-electricity distribution sectors are identical as shown in Fig. 1a and b.

In these two figures, all other bottom levels are nested by various CES functions. The intermediate inputs are CES combinations of domestic and imported goods. Energy-primary factor composites are CES combinations of energy-capital composite, labour and land. Unlike in ORANI-G, this model has a different treatment with regard to energy inputs because we believe that the emission pricing policy may lead to changes in energy production and energy consumption choices of producers as well as those of consumers; this may then lead to a shift from high emission-intensive energy products to low emission-intensive energy sources. Therefore, our model allows for substitution between energy inputs, especially substitution among electricity produced by various energy sources.

Deviating from ORANI-G, this CGE model treats energy and non-energy inputs separately, in particular a CES combination of energy inputs and capital is shown at the third level. The substitution between energy inputs and capital indicates the flexibility of the

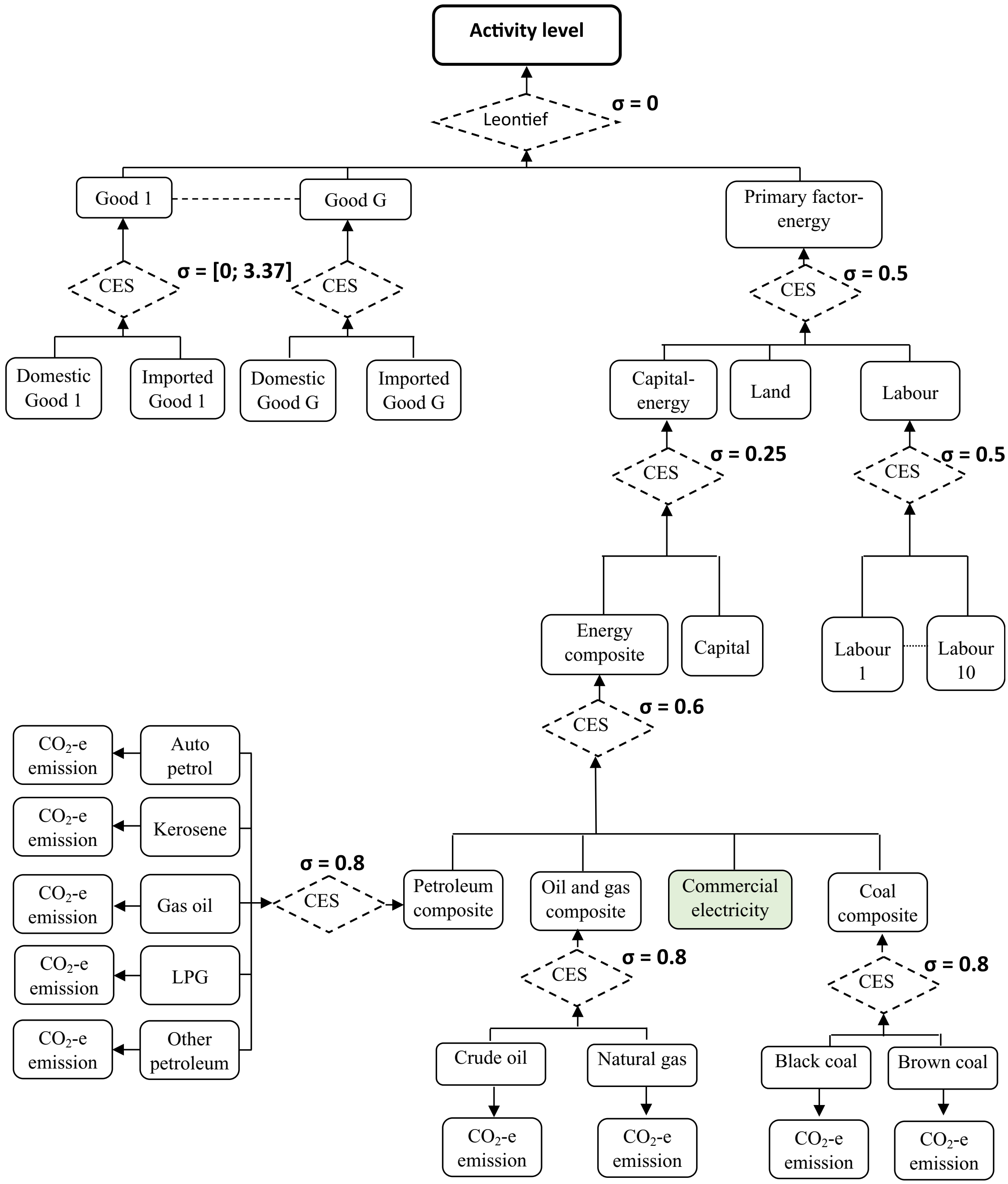

Fig. 1b. The production structure of non-electricity distribution sectors.
Note: Substitution elasticities were taken from Meng et al. (2013).

Australian economy's ability to adopt and utilise energy saving technology as increased energy input costs due to placing a price on carbon emissions. In general, the elasticity of substitution between energy and capital is small (Okagawa and Ban, 2008; Truong et al., 2007).

The substitutability of energy inputs is described at the fourth level through the CES function. The demand for composite energy is obtained from coal composite, oil and gas composite, and petroleum and commercial electricity composite. At the bottom level, the model presents the availability of substitution among sub-energy sectors via a CES function, such as the substitutability between black and brown coal in the coal composite, between oil and gas in the oil and gas composite, and between auto petroleum, kerosene, gas/fuel oil, liquefied petroleum gas and other petroleum gas in the petroleum composite.

To assess the effects of an ETS, the model incorporates carbon emissions accounting and carbon emissions in the model were treated as proportional to energy inputs used. Under the ETS, the quantity of emission generation is fixed and the price of emission permit is endogenously determined in the emissions supply and demand relations.

The demand functions of final users are similar to those in the ORANI-G model. For the structure of investment demand, it is the same as the structure of intermediate input demand. Thus, there are two levels in the structure of the investment demand: at the bottom level where the total cost of imported and domestic

commodities are minimised subject to the CES function and at the top level where the total cost of commodity composite is minimised subject to the Leontief function.

The structure of household demand is different from that of investment demand and intermediate input demand at the top level, but similar to those at the lower levels. In particular, the nesting structure for household demands is presented by a Klein-Rubin utility function at the top level, thus leading to the linear expenditure system. The household demand is a nested linear expenditure system (LES)-CES function.

Export demand depends on prices of commodities in foreign currency and government demand moves with household consumption. Unlike with the assumption of exogenous total or supernumerary household consumption in the ORANI-G model, we assume that total household consumption is proportional to total household income for each household group.

4. Database and simulation designs

4.1. Database

A social accounting matrix (SAM) is a core database of a CGE model. As a square matrix, the SAM describes all economic transactions and transfers among economic agents in an economy. In a SAM, a row records receipts of an agent, while outlays of an agent are displayed in columns. Each cell in a SAM represents simultaneous expenditure by an agent's column and a source of income by other agent's row, hence the total expenditure must be equal to the total income for each agent. Producers have receipts from selling commodities and simultaneously pay for intermediate inputs and primary factors. The factors of production are supplied by institutions, such as households, investors, government, and foreigners that, in turn, receive factor payments. Apart from these incomes, institutions receive incomes from other institutions in the income account, financial account and capital account through economic transactions or transfers. Due to the unique nature of this accounting, Round (2003b) stated that a SAM describes the structural characteristics of an economy.

The input-output data, which is a part of the SAM used in this study were obtained from the Australian input-output (I–O) Tables 2008–09, published by the Australian Bureau of Statistics (ABS) (2012c). The 2008-09 data was used for a critical reason. The SAM constructed in this study consists of data from the I–O tables, the I–O table (product details), the national greenhouse gas inventory, and the household expenditure survey (HES). Of these, the HES is the main source for disaggregating households into different groups based on their income levels. However, there are only two recent HES data: the HES 2009–10 and HES 2015–16. The latter has just been released and several months are needed for data compilation. Hence, for the most practical and compatible data, with the I–O data and emissions data, our only available choice was to use the HES 2009–10. As a result, these data were used together in order to ensure the compatible characteristics among data sources. We also considered updating the database by using other techniques, for example by using macroeconomic and sectoral economic projections in the modelling simulations to update the database to a recent year. However, this is not an optimal method and would highly distort the results rather than using the actual database. For example, although macro-economic projections can be consistent with the practice, the projections for sectors would not be adequately and accurately projected. In this instance, it would have been extremely challenging to use the simulation technique to obtain an updated database that is consistent with the real database in a particular future year which relates to production shares of each industry, consumption shares of each customer, household's income of each group, demands for labour and capital and so on. Consequently the results yielded from such an updated database would not be very accurate. Hence, in order to obtain the most reasonable results of the impacts of an ETS in Australia, we have used the actual database provided by the Government.

There are 111 sectors corresponding to 111 commodities in the original I–O tables, in which 4 energy sectors by column (commodities by row) were disaggregated into 18 sub-energy sectors (commodities) to form 125 sectors (commodities) for this study. The selection of sub-energy sectors used for the disaggregation was based on the information provided in the I–O table (product details) 2008–09. That is, these sub-energy sectors provide relatively important or high production and consumption values in the Australian economy. This table provides very detailed information of sub-commodities/sectors. In particular, this table shows which industries supply values of each sub-commodity and which industries consume values of these sub-commodities. In addition, this table also provides values of final uses of sub-commodities, as well as taxes and margins related to consumptions of these commodities. Hence, we had adequate information to disaggregate a main commodity (e.g. coal mining) into sub-commodities (e.g. black coal and brown coal). We applied the same procedure to disaggregate the other energy commodities in the SAM. Subsequently, we aggregated 125 sectors (commodities) into 45 sectors (commodities). In particular, the coal mining sector is divided into black and brown coal mining sectors; the oil and gas extraction sector is disaggregated into oil and gas extraction sectors; the petroleum sector is split into 5 sub-sectors, including automotive petrol, kerosene, gas/fuel oil, LPG, and other petroleum and coal product sectors. With regard to the electricity generation sector, the three sub-sectors including electricity generated from fossil fuels, hydro-electricity and other electricity generation sectors were disaggregated into 9 sub-sectors in this study, in which electricity produced by fossil fuels is disaggregated into black coal-fired, brown coal-fired, oil-fired, and gas-fired electricity generation sectors. Another electricity generation sector is disaggregated into electricity generated from wind, solar, biomass and biogas. The disaggregation by row and column for these energy sectors in the Supply table is shown in Tables A2 and A3 in Appendix A.

The data on flows of income and expenditure of institutional agents were collected not only from the I–O tables, but also from the Australian System of National Accounts (ASNA), published by the ABS (2011). To obtain data consistent with the I–O tables of 2008–09, this study used the data for institutions from the ASNA, 2010–11 for the year 2009. Therefore, the SAM presents the aggregated flows, transactions and transfers among all economic agents in the Australian economy for 2009, as shown in Table A1 in Appendix A.

A SAM also needs to display at least further minimal disaggregation of households and factor accounts to capture higher-order institutional features (Round, 2003a). To provide detailed impacts of the ETS on Australian households, such households were disaggregated into 20 different groups based on their income levels provided in the household expenditure survey (HES) 2009–10 (ABS, 2012a). This survey includes detailed information of 9800 households in Australia, such as the number of people in each household, current weekly income from different sources, current weekly expenditure on different goods and services, etc. We sorted these 9800 households based on their total incomes and then divided them into 20 different groups of which each group has 490 households. Subsequently, for each relevant variable in the survey, we calculated the shares of each household group relative to the total value of all household groups (i.e. 9800 households). We assumed that the information related to the 9800 households in the survey represents information for all households in Australia.

Subsequently, we used such ratios for disaggregation of each corresponding category in the SAM, that is for each flow in the income, capital, and financial accounts. Therefore, the receipts and payments of households as shown in Table A1 in Appendix A were divided into 20 groups.

Household income disaggregation by group and source in the income account is shown in Table A4 in Appendix A, in which the disaggregation of household income sourced from labour is divided into 10 occupational groups, based on the ratios of household income sourced from each occupation that were calculated from the data provided in the HES 2009–10. Household payments incorporate household consumption on goods and services and expenditure paid to institutions. Each source of these payments is divided into 20 household groups, based on ratios that were calculated from the data provided in the HES 2009–10. Table A5 in Appendix A shows the sources of household expenditure of each group.

Carbon emission data were obtained from the national greenhouse gas inventory (Department of the Environment, 2013b) for the year 2009 that incorporates emissions from fuel combustion, fugitive emissions, industrial processes, agriculture, waste, land use, land-use change and forestry. All these emissions are aggregated into three main sources, such as carbon emissions from stationary source (input emissions) that includes emissions from fuel combustion and from using halocarbons and hexafluoride in the industrial processes, as seen in Table B1 in Appendix B, carbon emissions from production activity (output emissions), as shown in Table B2 in Appendix B, and carbon emissions from household consumption (consumption emissions). The emissions are allocated to industries based on the proportion of energy used. The carbon emissions from all sources are disaggregated into emissions from domestic commodities and imported commodities.

The emission intensity was calculated for three emission categories, including input emission intensity, output emission intensity and consumption emission intensity. Based on the carbon emissions from domestic products and imported products by firms and private households provided in the GTAP database, 57 sectors and 4 types of fuels were mapped into 125 sectors and 12 types of fuels. Later this emissions data were aggregated into 45 sectors in this study. The emission intensity for domestic products and imported products for each sector by fuel are computed by dividing the emissions from domestic products (imported products) by the domestic purchases (import purchases) by firms or households. The ratio of emission intensity from domestic products and that from imported products was used to calculate the emission intensity for domestic and imported energy goods in this study.

The behavioural responses of economic agents are explained by the elasticity parameters that include the Armington elasticity, substitution elasticity between primary factors, between different types of labour, substitution elasticity between electricity generated from different sources, and between energy inputs obtained from ORANI-G database. In particular, the substitution elasticities shown in Fig. 1 follow Meng et al. (2013), which have been used in several climate change policy studies in Australia. In order to calculate expenditure elasticity for each household group and each commodity in the model of 20 household groups and 45 commodities, we used Australian household demand elasticity by 30 household groups and 14 commodities estimated by Cornwell and Creedy (1997). To use these elasticity estimates, 14 commodities were mapped into 45 commodities in the model, and 30 household groups were mapped into 20 household groups by mapping each 3 household groups into 2 household groups. These elasticity values were adjusted to satisfy the unity of Engel aggregation. The household expenditure elasticities are shown in Table C1 in Appendix C.

4.2. Simulation design

An ETS simulation was carried out in a short run framework, following Adams (2005). That is, we fixed the real wage rate, while we allowed employment levels to be flexible. In the short run simulation, the rate of return on capital was also allowed to change, whereas capital stock was fixed. In addition to these settings, three scenarios related to recycling options were formulated as provided in equations (1)–(3). First recycling scenario (Scenario INT) to reduce income tax is defined as:

$$\text{-delHTG1(h)} = \text{RCYC} * \text{S\_Income(h)} * \text{del\_REVENUE} + \text{f\_delINX(h)} \tag{1}$$

where delHTG1(h) are the changes in income taxes for each household group; RCYC is the share of recycled carbon tax or ETS revenues, in this study RCYC equals 0.5; S_Income (h) is the income tax share of each household group relative to total income tax paid by all household groups, the shares were computed by using the information in the HES 2009–10; del_REVENUE is the change in total carbon tax or ETS revenue; and f_delINX(h) is the shifter to reduce income tax.

In Scenario INT that uses the ETS revenue to reduce the income taxes, the variable f_delINX(h) in equation (1) is exogenous, while delHTG1(h) is endogenous. It means that the ETS revenue is recycled to each household group based on their initial income tax rates. Second recycling scenario (Scenario GOT) of changing pension and allowances is introduced via:

$$\text{delGTH(h)} = \text{RCYC*S\_Pension* del\_REVENUE} + \text{f\_delGTH(h)} \tag{2}$$

where delGTH(h) is the change in government transfer to each household group; RCYC and del_REVENUE are defined in equation (1); S_Pension is the share of pension and allowance that each household group currently receives from the government, the shares were computed by using the information in the HES 2009–10; and f_delGTH(h) is the shifter to recycle revenues to each household group.

In Scenario GOT that each household receives compensation from the government based on their shares of pension and allowance, the variable f_delGTH(h) in equation (2) is exogenous, while delGTH(h) is endogenous. The recycling scenario (Scenario ELS) to implement equal transfers to households is implemented via:

$$\text{delGTH(h)} = \text{RCYC*0.05* del\_REVENUE} + \text{f\_delGTH(h)} \tag{3}$$

In Scenario ELS each household group receives equal amounts of compensation from the government, the variable f_delGTH(h) in equation (3) is exogenous, while delGTH(h) is endogenous. Equations (2) and (3) are similar, except that the share of pension and allowance in equation (2) is replaced with the coefficient 0.05 in equation (3).

5. Results and discussion

To achieve the emission reduction target of 5 per cent below the 2000 level by 2020, the total emissions generated by 2020 is estimated to be 555 Mt CO_2-e (Department of the Environment, 2013a). The baseline emission level in 2009 was 575.679 Mt CO_2-e. To reach the target, the emissions should be reduced by 63.489 Mt CO_2-e (from the 2000 level), with a given annual emission growth rate of 0.72 per cent in the period 2009–2020. Under the ETS in this study, the Australian Government sets emission caps for industries covered by the ETS, in which the black coal-fired electricity and brown coal-fired electricity industries are responsible for 80 per

Table 1
Impacts of the ETS on macro-economic variables (percentage change).

Variables	NRR	INT	GOT	ELS
Emission permit price (A$)	20.607	20.618	20.613	20.615
Permit revenue (A$ million)	10280	10285	10283	10284
Nominal GDP	0.044	0.175	0.104	0.125
Real GDP	−0.300	−0.279	−0.290	−0.287
Real consumption	−0.186	0.004	−0.096	−0.066
Aggregate employment	−0.442	−0.420	−0.432	−0.429
Consumer price index	0.347	0.465	0.401	0.420
Export volume	−1.218	−1.520	−1.360	−1.408
Import volume	−0.322	−0.250	−0.286	−0.276
Terms of trade	0.124	0.156	0.139	0.144
Price of electricity	13.515	13.651	13.578	13.601

cent of this emission reduction target. The ETS is assumed to take place among Australian firms with an emission permit price that is determined by the market. The government accrues the revenue from auctions and there are no emission permits given away free to any polluters. Half of the revenue is assumed to compensate households through one of three revenue recycling options, including the personal income tax policy through an equal decrease in marginal income tax rate to all individuals (INT policy), an equal lump-sum transfer (ELS policy), and the increase in government transfers based on the current government pension and allowance transfer rates (GOT policy). The following sections compare and contrast the effects of the ETS with various revenue recycling options.

5.1. Impacts on macro-economic variables

To achieve the emissions reduction target, the emission permit price is estimated at around A$20 per tonne of CO2-e. Without compensation policies in place (NRR), this emission price causes a negative impact on the Australian economy as shown by projections of most macroeconomic variables in Table 1. The permit price results in higher production costs of goods and services, thus leading to a general rise in prices as reflected by an increased consumer price index by 0.347 per cent. The aggregate price of export commodities also rises by 0.124 per cent showing an improvement in the terms of trade in the short-run. The electricity price is estimated to increase at the highest percentage of over 13.5 per cent. This might be explained by the fact that the majority of electricity in Australia is produced by coal which is regarded as a high carbon-intensive product. The emissions permit price causes an increase in the electricity production cost that in turn leads to a higher electricity price.

The price increase causes reductions in real consumption by 0.186 per cent, export volume by 1.218 per cent and import volume by 0.322 per cent, thus together leading to a reduction of around 0.3 per cent in real GDP. The impact on real consumption is relatively smaller than the impact on real GDP because the ETS revenues are either used by the government or households regardless of who owns the revenues. In addition, exports of emission-intensive commodities also experience a highly unfavourable impact due to a price on emissions, which eventually increases their export prices. This would also yield higher negative effects on real GDP. The aggregate employment is projected to decline by 0.442 per cent with the price on emissions through an ETS.

To mitigate these negative impacts, 50 per cent of revenue raised from permit auctions is allocated to compensate households. The compensation policies create an improvement in the Australian economy, in which a reduction in personal income tax results in a higher economic efficiency than other revenue recycling options through making a higher nominal GDP increase and a lower real GDP decrease than other revenue recycling options. Moreover, the income tax reduction policy leads to a positive change in real household consumption, as opposed to the negative changes under other revenue recycling policies. Comparing the direct compensation policies, the results in Table 1 show that providing an equal lump-sum transfer to all household groups brings a better recovery for the Australian economy than the policy that transfers revenues to households on their pension and allowance rates, in which the former policy creates a lesser reduction in real GDP, real household consumption, and aggregate employment.

5.2. Impacts on households

Producers will initially bear increased production costs caused by the emission price, then pass such costs to customers as much as possible in order to maximise their profits. Indeed households, which are considered as final consumers, finally bear these costs through increased prices of goods and services they consume, leading to declined household consumption. In addition, producers also tend to shift backward these costs to investors and employees in the forms of lower returns on primary factors, resulting in decreased household income. These cumulatively have an impact on the distribution of income and welfare of all households. The effects of the ETS with various accompanied revenue recycling options on Australian households are presented in the following sections.

5.2.1. Household income

According to the HES 2009–10, households have derived income from five sources: labour, investment, unincorporated business, government pensions and allowances, and other sources. The contribution of each source to the total income of each household group is quite different. Therefore, this results in differential impacts of the ETS with and without compensation policies on Australian households. The effects of the ETS on the income of each household group depend mainly on the changes in returns on primary factors due to the emissions permit price and on the contribution of income sourced from primary factors to the total household income of each group.

As shown in Table 2, the first impression is that all household groups suffer reductions in income at different rates. Rich household groups seem to experience higher income reduction rates than poor groups. This is because main income sources of rich groups are employment income and investment, while poor groups have main income from government payments and allowances. The emissions permit price considerably affects wages, capital and land rentals, thus having larger impacts on high-income household groups. Therefore, the carbon pricing policy is progressive. For groups 4 and 5, percentage declines in their income are higher than other low-income household groups. This is due to the fact that capital income of these two groups is higher than other poor groups, thus a reduction in capital rental caused by the emissions permit price induces a higher percentage reduction in income than that of other low-income groups.

If the revenue is returned to households in the form of a direct compensation (ELS), all households obtain benefits with positive changes in income for low and middle-income household groups and smaller negative changes in income for wealthy household groups. As shown in Table 2, there are 18 out of 20 groups that would experience positive changes in their income under the ELS policy, compared to 14 out of 20 groups under the GOT policy. The middle-income household groups get higher benefits under the GOT policy than under the other compensation policies. By contrast, the INT policy brings more benefits for high-income household groups than for low-income groups, however all household groups experience negative changes in their income.

Table 2
Impact on household income by group (percentage change).

Group	NRR	INT	GOT	ELS
Group 1 (poorest)	−0.062	−0.045	2.091	3.414
Group 2	−0.084	−0.076	2.160	1.841
Group 3	−0.060	−0.055	2.223	1.739
Group 4	−0.212	−0.195	1.853	1.426
Group 5	−0.228	−0.206	1.664	1.155
Group 6	−0.092	−0.080	2.031	1.134
Group 7	−0.217	−0.193	1.691	0.926
Group 8	−0.163	−0.140	1.700	0.879
Group 9	−0.241	−0.205	1.352	0.699
Group 10	−0.223	−0.181	1.190	0.620
Group 11	−0.291	−0.229	0.747	0.467
Group 12	−0.294	−0.221	0.499	0.366
Group 13	−0.328	−0.237	0.176	0.252
Group 14	−0.262	−0.161	0.084	0.251
Group 15	−0.332	−0.219	−0.135	0.127
Group 16	−0.279	−0.168	−0.082	0.125
Group 17	−0.272	−0.157	−0.148	0.087
Group 18	−0.253	−0.135	−0.157	0.064
Group 19	−0.346	−0.223	−0.266	−0.075
Group 20 (richest)	−0.627	−0.500	−0.555	−0.431

5.2.2. Household consumption

The changes in consumption are quite different between household groups that depend mainly on changes in their income and their patterns of consumption of goods and services, as well as their responses to price changes. As shown in Table 3, the emissions permit price induces reductions in real consumption of all household groups, of which wealthy household groups suffer higher percentage declines than poor household groups; this outcome is consistent with changes in their income. The lower reduction rates in consumption of poor household groups are emerging because a higher proportion of their consumption is for subsistence goods and services that is not greatly affected by the emission price shock. By contrast, for rich household groups, the emissions permits price affects their consumption of luxury commodities substantially.

The reduction in the poorest household group's consumption is higher than that of the other three poor groups (groups 2, 3, and 4); this is because of their higher consumption levels and they spent more on luxury goods and services than these other poor groups. They have become the poorest household groups because of their loss in income sourced from their own incorporated business as indicated by the HES 2009–10. Therefore, the emissions permit price has a higher impact on their real consumption than that of the other poor groups. Results in Table 3 illustrate that various compensation policies may create an improvement to household consumption by different degrees. The revenue recycling option chosen depends on the purpose of the policy. In particular, the compensation under the GOT policy and ELS policy is sufficient to offset the negative effects caused by the ETS on consumption of the low and middle-income households, while rich household groups still bear losses in consumption but at smaller percentage declines than under the NRR policy. It seems that the GOT policy brings more benefits to the middle-income groups than under the ELS policy.

Table 3
Impact on household consumption by group.

Group	NRR	INT	GOT	ELS
Group 1 (poorest)	−0.039	−0.046	0.242	0.416
Group 2	−0.025	−0.030	0.106	0.086
Group 3	−0.021	−0.027	0.116	0.085
Group 4	−0.031	−0.037	0.109	0.078
Group 5	−0.039	−0.046	0.129	0.081
Group 6	−0.028	−0.036	0.166	0.081
Group 7	−0.045	−0.052	0.140	0.062
Group 8	−0.042	−0.050	0.147	0.060
Group 9	−0.055	−0.059	0.121	0.045
Group 10	−0.059	−0.058	0.114	0.040
Group 11	−0.080	−0.066	0.070	0.026
Group 12	−0.094	−0.058	0.041	0.015
Group 13	−0.111	−0.049	−0.018	−0.006
Group 14	−0.123	−0.020	−0.044	−0.004
Group 15	−0.151	−0.012	−0.106	−0.037
Group 16	−0.152	0.015	−0.102	−0.042
Group 17	−0.174	0.053	−0.142	−0.059
Group 18	−0.190	0.091	−0.165	−0.076
Group 19	−0.268	0.097	−0.247	−0.157
Group 20 (richest)	−0.591	0.045	−0.566	−0.487

Meanwhile, the personal income tax reduction (INT) creates more benefits for richer groups, in which the five richest household groups receive positive changes in their consumption, whereas nine poorest household groups still suffer decreased consumption, especially as these declines are mildly higher than those under the NRR policy. This is due to the fact that the income tax reduction policy does not result in a higher income for poor household groups, while the emissions permit price causes higher price increases for goods and services than the other compensation policies. In particular, the CPI increases by 0.465 per cent under the INT policy, compared to 0.347 per cent under the NRR policy, thus leading to higher reductions in consumption of poor household groups.

Table 4 presents the percentage change in consumption of energy commodities by household groups under the NRR policy. It is apparent that wealthy household groups reduce their consumption of energy products at higher rates than poor household groups because low-income household groups tend to spend a greater proportion of their income on these products than high-income household groups. For instance, the poorest group spent 13.6 per cent of their disposable income on petroleum products, 6.6 per cent on electricity, and 2.5 per cent on oil & gas, thus together totalling 22.8 per cent for energy products. Meanwhile, these proportions for the richest household group are 1.2 per cent, 0.9 per cent, and 0.3 per cent respectively which total 2.3 per cent for energy products. Therefore, as essential products, it is seemingly more difficult to reduce consumption of energy commodities of poor groups than rich groups. As seen in Table 4, the richest household group can cut the electricity consumption by 4 per cent compared to 0.9 per cent of the poorest group.

Among energy products, the highest electricity price increase caused by the ETS results in large percentage reduction in electricity consumption of all household groups. A higher reduction in electricity consumption of the poorest household groups compared to other poor groups can be explained by their greater response with electricity price changes. The decrease in household consumption of oil, gas, and petroleum products caused by the ETS is relatively small. To sum up, the ETS results in higher percentage declines in energy consumption of wealthier groups than poorer groups.

5.2.3. Household welfare impact

Equivalent Variation (EV) is used to highlight the welfare effects caused by price changes in the event of using an ETS for emissions abatement. The EV measures the amount of money needed to achieve a new level of utility at the initial price level or maximum amount that a consumer would be willing to pay to avoid a price change. The results in Fig. 2 illustrate that all household groups experience welfare losses at different degrees under the NRR policy. It is clear that poor household groups experience smaller welfare losses compared to rich household groups. On average, all Australian households suffer an aggregate welfare loss of A$1255 million.

Table 4
Energy consumption under the NRR policy (percentage change).

Group	Electricity consumption	Oil & gas consumption	Petroleum consumption	Energy consumption	Real consumption
Group 1 (poorest)	−0.952	−0.001	−0.023	−0.300	−0.039
Group 2	−0.552	0.000	−0.016	−0.196	−0.025
Group 3	−0.443	0.001	−0.018	−0.138	−0.021
Group 4	−0.406	−0.005	−0.042	−0.133	−0.031
Group 5	−0.221	−0.003	−0.061	−0.103	−0.039
Group 6	−0.278	0.000	−0.036	−0.101	−0.028
Group 7	−0.450	−0.006	−0.056	−0.168	−0.045
Group 8	−0.511	−0.004	−0.050	−0.187	−0.042
Group 9	−0.628	−0.009	−0.072	−0.217	−0.055
Group 10	−0.710	−0.010	−0.074	−0.256	−0.059
Group 11	−0.880	−0.018	−0.096	−0.319	−0.080
Group 12	−1.036	−0.023	−0.115	−0.374	−0.094
Group 13	−1.215	−0.032	−0.130	−0.444	−0.111
Group 14	−1.470	−0.031	−0.131	−0.543	−0.123
Group 15	−1.567	−0.046	−0.151	−0.566	−0.151
Group 16	−1.823	−0.044	−0.145	−0.652	−0.152
Group 17	−2.156	−0.052	−0.128	−0.743	−0.174
Group 18	−2.492	−0.056	−0.108	−0.853	−0.190
Group 19	−3.283	−0.109	−0.114	−1.055	−0.268
Group 20 (richest)	−4.352	−0.282	−0.187	−1.808	−0.591

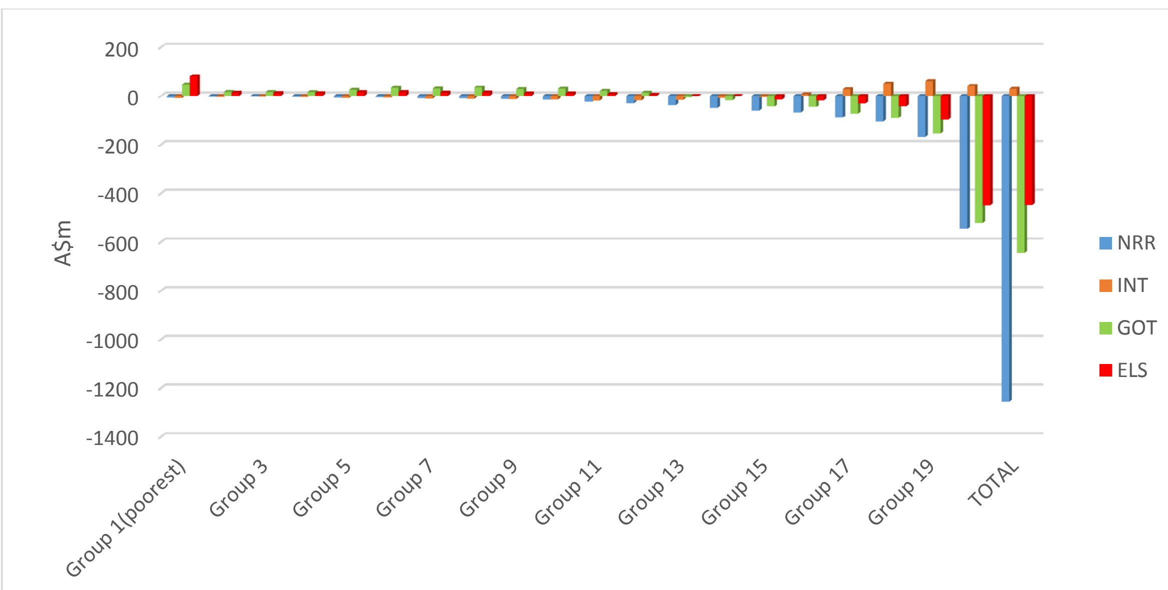

Fig. 2. Impacts of the ETS on equivalent variation (A$ million).

This aggregate loss is offset by the personal income tax reduction policy that brings an aggregate welfare gain of A$29 million to all Australian households. This kind of compensation results in welfare gains for the five richest household groups, meanwhile groups 1 to 9 reduce their welfare at higher rates than under the NRR policy.

By contrast, the GOT and ELS policies bring welfare gains for the 12 lowest income household groups, in which except for the poorest household group, the former brings more benefits for these household groups than for the latter. On average, these two compensation policies still produce an aggregate welfare loss, though the loss is smaller than under the NRR policy. These results reflect the change in household utility that is linked with the change in household income and household consumption.

5.3. Sensitivity analysis

The accuracy of the model's results depends on the elasticity values assigned to parameters, however they are often not precisely known. In this study, they are chosen from the ORANI-G database and other literature, therefore it is crucial to find out how variations in the values of these parameters affect the model results. A systematic sensitivity analysis (SSA) is a practical way to test the sensitivity of all parameters at once. The SSA is implemented through a Gaussian Quadrature, which is an optimisation method. Given the distribution of M exogenous parameters, the Gaussian Quadrature estimates the mean and the standard deviation of all endogenous variables by choosing the best possible N simulations. As can be seen from Table 5, with 95 per cent confidence, the results are robust with respect to the 50 per cent parameter variation, this is because the standard deviation of almost all endogenous variables is low and the SSA mean values are not significantly different from the original simulation results.

6. Conclusion

This paper evaluates the impact of achieving the emissions

Table 5
SSA of the ETS without compensation, 50% variation in parameters.

Variable (percentage change)	Mean	Standard deviation	Confidence Interval (95%)	
			Lower	Upper
Real GDP	−0.30092	0.01453	−0.36587	−0.23597
Real consumption	−0.18705	0.01091	−0.23582	−0.13828
Aggregate employment	−0.44386	0.02111	−0.53822	−0.34950
Export volume	−1.21927	0.06297	−1.50075	−0.93779
Import volume	−0.32235	0.02836	−0.44912	−0.19558
Consumer price index	0.34794	0.01539	0.27915	0.41673
Household consumption by groups (percentage change)				
Group 1 (poorest)	−0.03878	0.00146	−0.04531	−0.24130
Group 2	−0.02481	0.00095	−0.02906	−0.15469
Group 3	−0.02094	0.00083	−0.02465	−0.13113
Group 4	−0.03096	0.00133	−0.03691	−0.19593
Group 5	−0.03924	0.00177	−0.04715	−0.25001
Group 6	−0.02819	0.00114	−0.03329	−0.17698
Group 7	−0.04508	0.00195	−0.05380	−0.28555
Group 8	−0.04262	0.00175	−0.05044	−0.26810
Group 9	−0.05500	0.00246	−0.06600	−0.35000
Group 10	−0.05916	0.00261	−0.07083	−0.37576
Group 11	−0.08007	0.00391	−0.09755	−0.51611
Group 12	−0.09474	0.00481	−0.11624	−0.61434
Group 13	−0.11186	0.00602	−0.13877	−0.73216
Group 14	−0.12390	0.00683	−0.15443	−0.81420
Group 15	−0.15162	0.00884	−0.19113	−1.00599
Group 16	−0.15338	0.00886	−0.19298	−1.01602
Group 17	−0.17497	0.01047	−0.22177	−1.16629
Group 18	−0.19180	0.01158	−0.24356	−1.28052
Group 19	−0.27056	0.01658	−0.34467	−1.81125
Group 20 (richest)	−0.59660	0.03703	−0.76212	−4.00329

reduction target in Australia via implementing a domestic emissions trading scheme (ETS). We constructed a social accounting matrix (SAM) with details of energy sectors, multiple household and labour groups as the database of the CGE model, and employed a static CGE model to measure the effects of an ETS with a variety of revenue recycling options in place. The emissions permit price was estimated to be around A$20/t CO_2-e in order to meet the emissions target of below 5 per cent of the 2000 level by 2020. This emissions permit price leads to a small contraction in the Australian economy, including decreases in real GDP, real household consumption and trade volume. In all scenarios, the real GDP would only decline by 0.28−0.3 per cent, signalling that Australia can achieve the 2020 emissions target with a small cost to the economy. Due to high emission-intensity, prices of energy commodities yield high percentage changes, in which electricity price was estimated to increase at the highest percentage of over 13 per cent.

The proposed compensation policies to households are likely to create an improvement in the macro-economy. However it also seems that there is a trade-off between efficiency and equity. The income tax reduction policy induces more economic efficiency in the Australian economy than the other revenue recycling options. For example, the income tax reduction policy causes a lower real GDP decrease and a positive real aggregate household consumption change. However, this policy also results in inequity by providing a positive percentage change in real household consumption and welfare gain for wealthy household groups. Whereas, the equal lump-sum transfer policy (ELS) leads to higher equity benefits among household groups, with over-compensation to the poor, and the rich who lose by lowering their income, consumption and welfare. Middle-income household groups obtain larger benefits from the increased government payments to households based on their current pension and allowance rates than that emerge from the other compensation policies.

The findings of this study make a valuable contribution to the literature of climate change policies and their impact on households. Rich household groups would pay income taxes at much higher rates than the poor, hence if the revenue of the ETS is recycled to households based on their current income tax rates, rich household groups are much better off than the poor. If the target is to help poor household groups to avoid likely substantial impacts of an ETS, the government should allocate the revenue based on their currently received pension and allowance rates, or implementing equal transfer to all household groups. These findings are useful for policymakers in order to design appropriate supporting policies to moderate the impacts on the economy and different household groups. It is particularly important in Australia, as poor household groups mainly receive government allowances for their subsistence. Hence, a supporting policy that is targeted to help them is a very important aspect in designing a climate change policy in Australia. On one hand, it helps Australia to achieve the committed emission target and while on the other hand, the impacts on the economy and households are lightened. These findings and implications for different household groups of an ETS with different compensation policies in place has broader validity for many countries which may contemplate adopting climate change policies to reduce their own emissions.

The limitations of the study largely lie in the application of a static CGE model. A static CGE model only measures the effects of the ETS in the short run and does not track variables over time, therefore this model does not reflect the changes in capital and investment decisions. Such decisions may cause producers to adopt low emission technologies. In addition, such a static CGE model does not allow for implementing banking and borrowing emission permits. Some previous studies which implemented banking and borrowing emission permits have shown reduction in the volatility of the emission permit price when the ETS is in place.

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Appendix A. Social Accounting Matrix (SAM)

Table A1
The SAM for the Australian economy (A$ million), year 2009.

Classification	Order	Items	Production Activities						Factors of production			Income Account				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
			Industry	Dom-Com	Imp-Com	Margins	Tax on products	Tax on production	Labour	Capital	Land	HH	Non-corp	Corp	Gov	For
Production Activities	1	Industry		2220819		228544										
	2	Dom-Com	1036363									453244			215992	256248
	3	Imp-Com	153282									64189			2902	7813
	4	Margins	78504									106496			1703	21101
	5	Tax on products	12339									52285			0	−592
	6	Tax on production	35868												17628	
Factors of production	7	Labour	596098													1717
	8	Capital	528069													
	9	land	8840													
Income Account	10	HH							594598	175291	8840	4023	17742	129755	130549	8432
	11	Non-corp								266949		7145	5704	22946	381	6922
	12	Corp								59520		99797	70139	7764	10132	5315
	13	Gov					83343	53496		26308		137262	56525	18660	1427	9955
	14	For			277218				3217			2231	21305	42657	10374	16365
Financial Account	15	HH														
	16	Non-corp														
	17	Corp														
	18	Gov														
	19	For														
Capital Account	20	HH										142558				
	21	Non-corp											138633			
	22	Corp												30884		
	23	Gov													−4113	
	24	For														40090
	25	non-flow items														
	26	Total	2449363	2220819	277218	228544	83343	53496	597815	528068	8840	1069230	310047	252667	386976	373368

Classification	Order	Items	Financial Account					Capital Account					Total
			15	16	17	18	19	20	21	22	23	24	
			HH	Non-corp	Corp	Gov	For	HH	Non-corp	Corp	Gov	For	
Production Activities	1	Industry											2449363
	2	Dom-Com						81935	136140	6870	34027		2220819
	3	Imp-Com						16300	24910	1937	5884		277218
	4	Margins						6940	11298	643	1858		228543
	5	Tax on products						6517	10806	552	1436		83343
	6	Tax on production											53496
Factors of production	7	Labour											597815
	8	Capital											528069
	9	land											8840
Income Account	10	HH											1069230
	11	Non-corp											310047
	12	Corp											252667
	13	Gov											386976
	14	For											373368
Financial Account	15	HH	−1142	−438	116005	6553	10722						131700
	16	Non-corp	9106	11666	22912	10849	16266						70800
	17	Corp	42033	63175	12678	14379	22434						154700
	18	Gov	8230	13515	−17286	15810	9431						29700
	19	For	10472	59181	6991	22709	147						99500
Capital Account	20	HH							202		2132		144892
	21	Non-corp						373			4616		143622
	22	Corp											30884
	23	Gov						161	1449				−2503
	24	For									367		40457
	25	non-flow items	63000	−76300	13400	−40600	40500	32666	−41183	20881	−52824	40457	
	26	Total	131700	70800	154700	29700	99500	144891	143622	30884	−2503	40457	

Note: Dom-Com: domestic commodities; Imp-Com: imported commodities; HH: households; Non-corp: non-financial corporation; Corp: financial corporation; Gov: government; For: foreigners.
Source: Computed and collected from the I–O tables, 2008–2009, the ASNA, 2010–2011 (ABS, 2012a).

Table A2
Disaggregated energy industries by row and column in the Supply Table (A$ million).

Industry …… / Commodity	Coal mining	Black coal k1	Brown coal k2	Oil & gas extraction	Oil k3	Gas k4	Petroleum & Coal products	Auto petrol k5	Kerosene k6	Gas/fuel oil k7	LPG k8	Other petrol k9	……	Australian Supply
…..	a1	a1*k1	a1*k2	b1	b1*k3	b1*k4	c1	c1*k5	c1*k6	c1*k7	c1*k8	c1*k9		
Coal mining	**57407**													57407
Black coal		56423												56423
Brown coal			984											984
Oil & gas extraction				**33085**										33085
Oil					16151									16151
Gas						16934								16934
Petroleum & Coal products							**27722**							31233
Auto petrol								11642					1846	13488
Kerosene									3883					3883
Gas/fuel oil										8613			1278	9891
LPG											583			583
Other petrol												3001	387	3388
Professional, Scientific and Technical service	1298	1276	22	734	358	376	122	53	15	39	2	13		
….	ak	ak*k1	ak*k2	bk	bk*k3	bk*k4	ck	ck*k5	ck*k6	ck*k7	ck*k8	ck*k9		

Note: k1 = 56423/57407; k2 = 984/57407; k3 = 16151/33085; k4 = 16934/33085; k5 = 13488/31233; k6 = 3883/31233; k7 = 9891/31233; k8 = 583/31233; k9 = 3388/31233.
Source: Collected from the I–O table (product details) 2008–2009 and adjusted by the authors (ABS, 2012b).

Table A3
Disaggregated electricity generation sector by row and column in Supply Table (A$ million).

Industry / Commodity		Elec generation	Electricity generation from fossil fuels	Elec-black coal l1	Elec-brown coal l2	Elec-oil l3	Elec-gas l4	Hydro elec	Elec generation n.e.c l5	Elec-wind l6	Elec-solar l7	Elec-biomass l8	Elec-biogas	Commerical elec l9	Australian supply
….	….													…	
Electricity generation	965	13057												313	14335
Electricity generation from fossil fuels	965		11753											284	13002
Electricity-black coal				7267										162	7430
Electricity-brown coal					3164									71	3235
Electricity-oil						224								5	229
Electricity-gas	965						1097							46	2108
Hydroelectricity								1023						23	1046
Other electricity generation									281					6	287
Electricity-wind										170				4	174
Electricity-solar											7			0	7
Electricity-biomass												64		1	66
Electricity-biogas													39	1	40
…															
Construction		651		651*l1	651*l2	651*l3		651*l5		651*l6	651*l7	651*l8	651*l9		
…..															

Note: l1 = 7430/14335; l2 = 3235/14335; l3 = 229/14335; l4 = 2108/14335; l5 = 1046/14335; l6 = 174/14335; l7 = 7/14335; l8 = 66/14335; l9 = 40/14335.
Source: Collected from the I–O table (product details), 2008–2009 and adjusted by the authors (ABS, 2012b).

Table A4
Household income disaggregation by group and source (A$ million).

Group	Total income	Labour	Capital	Land	Social Assistant Benefit	Current Transfer	Other sources
Group 1	7418	672	209	61	3523	649	2304
Group 2	13390	231	577	111	6685	1083	4704
Group 3	14316	136	419	118	7271	1178	5194
Group 4	15797	348	1866	131	7084	1414	4955
Group 5	18773	840	2376	155	7678	1707	6017
Group 6	21102	741	995	174	9915	1808	7468
Group 7	22796	1432	2706	188	9547	1896	7027
Group 8	25029	2164	2188	207	10082	2257	8131
Group 9	28008	3994	3623	232	9590	2277	8293
Group 10	31462	6369	3527	260	9572	2251	9483
Group 11	35703	11485	5250	295	7918	1945	8810
Group 12	41776	17640	5873	345	6976	1740	9201
Group 13	49007	25636	7707	405	4977	1340	8942
Group 14	57036	35665	6722	472	3742	1033	9403
Group 15	66119	44860	10037	547	2119	663	7893
Group 16	76454	53331	9293	632	2426	741	10031
Group 17	89033	66021	10299	736	1408	467	10102
Group 18	105288	79851	11244	871	963	441	11918
Group 19	131290	97622	20728	1085	689	318	10848
Group 20	219436	145560	69652	1814	656	457	1296
TOTAL	1069230	594598	175291	8840	112820	25665	152018

Source: Collected from the Household Expenditure Survey, 2009–10 and computed by the authors (ABS, 2010).

Table A5
Household expenditure disaggregation by group and item (A$ million).

Group	Commodity (domestic)	Commodity (imported)	Margin	Tax on products	Income tax	Other sources	Total expenditure
Group 1	13346	1800	2932	1372	0	2564	22013
Group 2	9922	1209	3452	935	0	965	16483
Group 3	9733	1312	1612	907	0	894	14458
Group 4	11163	1416	673	960	0	1190	15403
Group 5	13152	1909	2949	1339	0	1608	20956
Group 6	14043	1995	2414	1450	16	1736	21654
Group 7	14594	2160	3173	1564	13	1517	23022
Group 8	15573	2138	4126	1643	29	1781	25292
Group 9	16363	2219	2342	1879	207	1862	24872
Group 10	17501	2382	3907	1937	538	2643	28909
Group 11	19727	2737	4475	2312	1200	3553	34004
Group 12	20935	2825	5152	2610	2467	4595	38585
Group 13	22368	3166	5130	2683	4047	5550	42945
Group 14	26301	3640	7473	3208	5823	7179	53623
Group 15	26387	3887	6594	3466	8215	8513	57063
Group 16	29666	4202	7038	3686	10292	9752	64636
Group 17	34799	5106	7381	4143	13569	11003	76002
Group 18	36724	5537	8115	4704	17291	13564	85935
Group 19	44298	6191	6763	5075	23737	15072	101135
Group 20	56649	8356	20794	6412	48881	18590	159683
Total	453244	64189	106496	52285	136326	114132	926672

Source: Collected from the Household Expenditure Survey 2009–10 and computed by the authors (ABS, 2010).

Appendix B. Carbon emissions data

Table B1
Carbon emissions from stationary source (kilo tonne).

Commodity / Industries	Black coal	Brown coal	Oil	Gas	Automotive petrol	Kerosene	Gas/ fuel oil	LPG	Wood, Paper & Print	Other petroleum	Furniture & Equipment	Road transport	Other transports	Other services	Total
Agriculture, forestry, fishing	0	161	0	4	174	0	2978	58	0	0	34	2	1	0	3413
Black coal	0	0	0	3	1	0	2282	0	0	29	14	3	19	0	2351
Brown coal	0	15	0	0	0	0	40	0	0	1	0	0	0	0	56
Oil	0	0	0	0	0	0	36	2	0	30	1	0	2	0	71
Gas	0	0	0	14664	0	0	38	2	0	32	1	0	2	0	14738
Mining	40	0	0	124	0	0	2195	56	0	81	23	4	5	0	2528
Food, beverages, tobacco	1250	0	0	1412	0	0	76	34	50	0	3	7	2	0	2834
Textiles, clothing, footwear	63	0	0	247	0	0	0	8	0	31	0	0	0	0	349
Wood, paper, printing	421	0	0	1048	0	0	13	4	30	4	1	3	2	0	1526
Automotive petrol	0	0	0	17	0	0	15	7	0	313	0	0	0	0	353
Kerosene	0	0	0	0	0	0	4	2	0	90	0	0	0	0	97
Gas oil or fuel oil	0	0	0	0	0	0	11	5	0	230	0	0	0	0	247
Liquefied petroleum gas	0	0	0	96	0	0	1	0	0	14	0	0	0	0	111
Other petroleum, coal products	1017	9	0	204	0	0	4	2	0	79	0	0	0	0	1315
Chemical products	592	19	0	1183	0	0	15	297	0	887	1	2	1	0	2996
Iron and steel	2274	0	0	971	0	0	35	3	0	0	1	2	5	0	3291
Other metal products	3745	81	0	6055	0	0	1345	23	2	17	4	3	5	0	11280
Furniture and equipment	0	0	0	243	0	0	36	27	0	0	26	2	4	0	339
Other manufacturing	2500	0	0	2655	0	0	88	170	1	177	1	3	3	0	5599
Elec -black coal	115125	0	0	0	0	0	0	0	0	0	1	0	0	0	115126
Elec -brown coal	0	68679	0	0	0	0	0	0	0	0	0	0	0	0	68679
Elec-oil	0	0	0	0	0	0	1661	0	0	0	0	0	0	0	1661
Elec- gas	0	0	0	19660	0	0	0	0	0	0	0	0	0	0	19660
Hydro-electricity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elec -wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table B1 (*continued*)

Commodity / Industries	Black coal	Brown coal	Oil	Gas	Automotive petrol	Kerosene	Gas/ fuel oil	LPG	Wood, Paper & Print	Other petroleum	Furniture & Equipment	Road transport	Other transports	Other services	Total
Elec-solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elec-biomass	0	0	0	0	0	0	0	0	165	0	0	0	0	0	165
Elec-biogas	0	0	0	0	0	0	0	0	0	0	0	0	0	59	59
Commercial electricity	0	40	0	2	0	0	3	0	0	0	1	0	0	0	47
Gas supply	0	0	0	0	0	0	2	0	0	0	0	0	0	0	3
Water, sewerage services	0	0	0	2	0	0	17	0	0	0	15	0	1	0	35
Construction services	0	95	0	293	7	0	1254	18	0	0	42	9	3	0	1722
Wholesale trade	0	0	0	48	0	0	109	10	0	0	65	20	16	0	268
Retail trade	0	0	0	120	0	0	53	8	0	0	89	3	3	0	276
Accommodation, restaurant	0	0	0	467	0	0	8	29	0	0	47	0	1	0	552
Road transport	0	0	0	96	24073	0	15335	2072	14	0	1	37	0	0	41628
Other transports	0	0	0	352	753	3830	2078	29	0	0	9	10	10	0	7072
Communication services	0	0	0	139	0	0	32	3	0	0	18	7	13	0	212
Finance and insurance	0	0	0	24	0	0	18	3	0	0	0	1	1	0	46
Property, business services	0	0	0	222	0	0	77	7	0	0	74	11	31	0	422
Public services	0	0	0	119	7	0	279	10	0	0	24	10	9	0	457
Education and training	0	0	0	76	0	0	5	1	0	0	8	3	3	0	96
Health, community services	0	0	0	159	0	0	6	6	0	0	19	5	2	0	197
Art, recreation services	0	0	0	15	0	0	4	1	0	0	28	1	2	0	51
Other services	0	0	0	91	0	10	26	4	0	0	54	2	1	0	188
Total	127027	69098	1	50812	25015	3840	30179	2900	262	2013	606	151	148	59	312112

Source: Computed from data provided by the National Greenhouse Gas Inventory (Department of the Environment, 2013a,b).

Table B2
Carbon emissions from activity source (kilo tonne).

	Agriculture, forestry, fishing	Black coal	Brown coal	Oil	Gas	Food, beverages, tobacco	Chemical products	Iron and steel	Other metal products	Furniture and equipment	Other manufacturing	Gas supply	Water, sewerage services	Other services	Total
Agriculture, forestry, fishing	105513	0	0	0	0	0	0	0	0	0	0	0	0	0	105513
Black coal	0	28329	0	0	0	0	0	0	0	0	0	0	0	0	28329
Brown coal	0	0	494	0	0	0	0	0	0	0	0	0	0	0	494
Oil	0	0	0	1605	0	0	0	0	0	0	0	0	0	0	1605
Gas	0	0	0	0	6769	0	0	0	0	0	0	0	0	0	6769
Food, beverages, tobacco	1321	0	0	0	0	154	0	0	0	0	0	0	0	0	1475
Chemical products	0	0	0	0	0	0	5929	0	0	0	0	0	0	0	5929
Iron and steel	0	0	0	0	0	0	0	6020	0	0	0	0	0	0	6020
Other metal products	0	0	0	0	0	0	0	24.2	3288	0	0	0	0	0	3312
Other manufacturing	0	0	0	0	0	0	0	0	25.8	0	6051	0	0	0	6077
Electricity -brown coal	0	0	0	0	0	0	0.023	0	0	0	0	0	0	0	0.023
Electricity- gas	0	0	0	0	0	0.051	21.5	2.76	17.4	0	0	0	0	0	41.7
Gas supply	0	0	0	0	0	0	0	0	0	0	0	3015	0	0	3015
Water, sewerage services	0	0	0	0	0	0	0	0	0	0	0	0	2488	0	2488
Construction services	1717	0	0	0	0	0.516	15.8	3.37	7.34	0	7.81	0	366	87	2205
Wholesale trade	0	0	0	0	0	2.61	167	84	10.9	0	4.88	0	0	0	269
Road transport	329	0	0	0	0	0	0	0	0	0	0	0	0	0	329
Property, business services	2119	0	0	0	0	4.66	179	160	95	0	471	0	25.6	423	3477
Other services	0	0	0	0	0	0.002	0.359	0	0.062	0	0.976	0	0	9887	9888
Total	110999	28329	494	1605	6769	162	6313	6294	3445	0	6536	3015	2880	10397	187237

Source: Computed from the data provided by the National Greenhouse Gas Inventory (Department of the Environment, 2013a,b).

Appendix C. Elasticity parameters

Table C1
Household expenditure elasticities.

Industries	G 1	G 2	G 3	G 4	G 5	G 6	G 7	G 8	G 9	G 10	G 11	G 12	G 13	G 14	G 15	G 16	G 17	G 18	G 19	G 20
Agriculture, forestry, fishing	0.94	0.89	0.83	0.83	0.77	0.78	0.77	0.77	0.78	0.78	0.80	0.80	0.78	0.80	0.79	0.80	0.80	0.81	0.87	0.85
Black coal	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Brown coal	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Oil	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Gas	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Mining	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Food, beverages, tobacco	0.94	0.89	0.83	0.83	0.77	0.78	0.77	0.77	0.78	0.78	0.80	0.80	0.78	0.80	0.79	0.80	0.80	0.81	0.87	0.85
Textiles, clothing, footwear	1.06	1.13	1.30	1.45	1.55	1.63	1.60	1.60	1.65	1.65	1.66	1.65	1.65	1.70	1.71	1.71	1.67	1.71	1.69	1.76
Wood, paper, printing	1.30	1.47	1.72	1.82	1.88	1.97	1.83	1.77	1.82	1.82	1.76	1.75	1.73	1.65	1.57	1.59	1.58	1.59	1.59	1.69
Automotive petrol	1.17	1.29	1.57	1.79	1.88	1.77	1.65	1.65	1.71	1.68	1.55	1.56	1.48	1.38	1.24	1.21	0.92	0.72	0.50	0.36
Kerosene	1.17	1.29	1.57	1.79	1.88	1.77	1.65	1.65	1.71	1.68	1.55	1.56	1.48	1.38	1.24	1.21	0.92	0.72	0.50	0.36
Gas oil or fuel oil	1.17	1.29	1.57	1.79	1.88	1.77	1.65	1.65	1.71	1.68	1.55	1.56	1.48	1.38	1.24	1.21	0.92	0.72	0.50	0.36
Liquefied petroleum gas	1.17	1.29	1.57	1.79	1.88	1.77	1.65	1.65	1.71	1.68	1.55	1.56	1.48	1.38	1.24	1.21	0.92	0.72	0.50	0.36
Other petroleum, coal products	1.17	1.29	1.57	1.79	1.88	1.77	1.65	1.65	1.71	1.68	1.55	1.56	1.48	1.38	1.24	1.21	0.92	0.72	0.50	0.36
Chemical products	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Iron and steel	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Other metal products	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Furniture and equipment	1.30	1.47	1.72	1.82	1.88	1.97	1.83	1.77	1.82	1.82	1.76	1.75	1.73	1.65	1.57	1.59	1.58	1.59	1.59	1.69
Other manufacturing	1.11	1.30	1.49	1.51	1.61	1.69	1.58	1.63	1.62	1.62	1.67	1.67	1.64	1.62	1.56	1.57	1.61	1.64	1.57	1.65
Electricity -black coal	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Electricity -brown coal	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Electricity-oil	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Electricity- gas	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Hydro-electricity	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Electricity -wind	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Electricity-solar	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Electricity-biomass	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Electricity-biogas	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Commercial electricity	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Gas supply	0.91	0.83	0.64	0.52	0.22	0.27	0.40	0.44	0.49	0.51	0.55	0.56	0.61	0.60	0.61	0.64	0.65	0.67	0.74	0.69
Water, sewerage services	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Construction services	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Wholesale trade	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Retail trade	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Accommodation, restaurant	1.05	1.11	1.28	1.40	1.52	1.59	1.66	1.71	1.80	1.76	1.74	1.75	1.75	1.79	1.89	1.91	1.89	1.92	1.86	1.86
Road transport	1.17	1.29	1.57	1.79	1.88	1.77	1.65	1.65	1.71	1.68	1.55	1.56	1.48	1.38	1.24	1.21	0.92	0.72	0.50	0.36
Other transports	1.17	1.29	1.57	1.79	1.88	1.77	1.65	1.65	1.71	1.68	1.55	1.56	1.48	1.38	1.24	1.21	0.92	0.72	0.50	0.36
Communication services	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Finance and insurance	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Property, business services	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Public services	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Education and training	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68
Health, community services	0.95	0.93	0.91	1.00	1.00	0.94	0.89	0.84	0.73	0.68	0.40	0.58	0.74	0.76	0.78	0.78	0.75	0.75	0.79	0.74
Art, recreation services	1.05	1.11	1.28	1.40	1.52	1.59	1.66	1.71	1.80	1.76	1.74	1.75	1.75	1.79	1.89	1.91	1.89	1.92	1.86	1.86
Other services	0.93	0.87	0.76	0.73	0.60	0.60	0.61	0.62	0.62	0.62	0.66	0.65	0.64	0.64	0.64	0.65	0.68	0.69	0.75	0.68

Source: Authors' calculation.

References

Australian Bureau Statistics (ABS), 2010. Australian Bureau of Statistics remote access data laboratory (RADL) household expenditure, 2009-2010 Expanded Reissued 3. https://www7.abs.gov.au/forums/radl.nsf. (Accessed 17 February 2017).

Australian Bureau Statistics (ABS), 2011. Australian system of national accounts, 2010-11. Catalogue No. 5204, 2011. http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5204.02010-11. (Accessed 18 February 2017).

Australian Bureau Statistics (ABS), 2012a. Australian national accounts: input-output tables, 2008-09. Catalogue No. 5209, 2012. http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/5209.0.55.001Main+Features12008-09. (Accessed 20 February 2017).

Australian Bureau Statistics (ABS), 2012b. Australian national accounts: input-output tables (product details), 2008-2009. Catalogue No. 5215, 2012. http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5215.0.55.0012008-09?OpenDocument. (Accessed 18 February 2017).

Adams, P.D., 2005. Interpretation of results from CGE models such as GTAP. J. Pol. Model. 27 (8), 941–959.

Adams, P.D., 2007. Insurance against catastrophic climate change: how much will an emissions trading scheme cost Australia? Aust. Econ. Rev. 40, 432–452.

Arndt, D., Johnson, G.C., Blunden, J., 2015. State of the climate in 2014: special supplement to the. Bull. Am. Meteorol. Soc. 96 (7).

Beck, M., Rivers, N., Wigle, R., Yonezawa, H., 2015. Carbon tax and revenue recycling: impacts on households in British Columbia. Resour. Energy Econ. 41, 40–69.

Beznoska, M., Cludius, J., Steiner, V., 2012. The Incidence of the European Union Emissions Trading System and the Role of Revenue Recycling: Empirical Evidence from Combined Industry-And Household-Level Data. German Institute for Economic Research, Berlin. Discussion Papers, No 1227.

Buddelmeyer, H., Hérault, N., Kalb, G., van Zijll de Jong, M., 2012. Linking a microsimulation model to A dynamic CGE model: climate change mitigation policies and income distribution in Australia. Int. J. Microsimul. 5, 40–58.

Climate Change Authority, 2014. Reducing Australia's Greenhouse Gas Emission - Targets and Progress Review - Final Report. Australia, Canberra.

Cornwell, A., Creedy, J., 1997. Environmental Taxes and Economic Welfare: Reducing Carbon Dioxide Emissions. Edward Elgar, Cheltenham,UK.

Cramton, P., Kerr, S., 2002. Tradeable carbon permit auctions: how and why to auction not grandfather. Energy Policy 30, 333–345.

Department of the Environment, 2013a. National Greenhouse Gas Inventory - Kyoto Protocol Classifications. http://ageis.climatechange.gov.au/NGGI.aspx. (Accessed 20 February 2017).

Department of the Environment, 2013b. Australia's Abatement Task and 2013 Emissions Projections. Australia, Canberra.

Dixon, P.B., Jorgenson, D., 2013. Handbook of Computable General Equilibrium

Modeling SET, 1A and 1B. Elsevier, Amsterdam.
Garnaut, R., 2011. The Garnaut Review 2011: Australia in the Global Response to Climate Change. Cambridge University Press.
Grudnoff, M., 2011. Direct Action: Good Politics, Bad Policy. http://www.apo.org.au/commentary/direct-action-good-politics-bad-policy. (Accessed 18 February 2018).
Hatfield-Dodds, S., Feeney, K., Garcia, C., Proctor, W., 2011. The Carbon Price and the Cost of Living- Summary Report: Assessing the Impacts on Consumer Prices and Households. A report to The Climate Institute prepared by CSIRO and AECOM, CSIRO/AECOM. Australia, Sydney.
Horridge, M., 2003. ORANI-G: A Generic Single-Country Computable General Equilibrium Model. Centre of Policy Studies, prepared for the practical GE modelling course, Monash Univeristy, Melbourne.
IPCC, 2014. Climate change 2014: synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental Panel on climate change. In: Pachauri, Rajendra K., Meyer, Leo (Eds.), The Core Writing Team. IPCC, Switzerland, Geneva.
Kopsch, F., 2012. Aviation and the EU Emissions Trading Scheme—lessons learned from previous emissions trading schemes. Energy Policy 49, 770–773.
Li, W., Jia, Z., 2016. The impact of emission trading scheme and the ratio of free quota: a dynamic recursive CGE model in China. Appl. Energy 174, 1–14.
Lin, B., Jia, Z., 2017. The impact of Emission Trading Scheme (ETS) and the choice of coverage industry in ETS: a case study in China. Appl. Energy 205, 1512–1527.
Lin, B., Jia, Z., 2018a. Transfer payments in emission trading markets: a perspective of rural and urban residents in China. J. Clean. Prod. 204, 753–766.
Lin, B., Jia, Z., 2018b. Impact of quota decline scheme of emission trading in China: a dynamic recursive CGE model. Energy 149, 190–203.
Lin, B., Jia, Z., 2018c. The energy, environmental and economic impacts of carbon tax rate and taxation industry: a CGE based study in China. Energy 159, 558–568.
Liu, Y., Lu, Y., 2015. The economic impact of different carbon tax revenue recycling schemes in China: a model-based scenario analysis. Appl. Energy 141, 96–105.
Liu, X., Wang, B., Du, M., Zhang, N., 2018. Potential economic gains and emissions reduction on carbon emissions trading for China's large-scale thermal power plants. J. Clean. Prod. 204, 247–257.
Meng, S., Siriwardana, M., McNeill, J., 2013. The environmental and economic impact of the carbon tax in Australia. Environ. Resour. Econ. 54 (3), 313–332.
Meng, S., Siriwardana, M., McNeill, J., 2014. The impact of the Australian carbon tax on industries and households. Margin: J. Appl. Econ. Res. 8, 15–37.
Meng, S., Siriwardana, M., McNeill, J., Nelson, T., 2018. The impact of an ETS on the Australian energy sector: an integrated CGE and electricity modelling approach. Energy Econ. 69, 213–224.
Nong, D., Siriwardana, M., 2017. Australia's Emissions Reduction Fund in an international context. Econ. Anal. Policy 54, 123–134.
Nong, D., Siriwardana, M., 2018a. Potential impacts of the emissions reduction fund on the Australian economy. Energy Econ. 74, 387–398.
Nong, D., Siriwardana, M., 2018b. Effects on the US economy of its proposed withdrawal from the paris agreement: a quantitative assessment. Energy 159, 621–629.
Nong, D., Meng, S., Siriwardana, M., 2017. An assessment of a proposed ETS in Australia by using the MONASH-Green model. Energy Policy 108, 281–291.
O'Gorman, M., Jotzo, F., 2014. Impact of the Carbon Price on Australia's Electricity Demand, Supply and Emissions. CCEP Working Paper 1411. Crawford School of Public Policy, The Australian National University, Canberra.
Okagawa, A., Ban, K., 2008. Estimation of Substitution Elasticities for CGE Models. Discussion Papers in Economics and Business, Japan.
Orlov, A., Grethe, H., McDonald, S., 2013. Carbon taxation in Russia: prospects for a double dividend and improved energy efficiency. Energy Econ. 37, 128–140.
Parry, I.W., 2002. Are tradable emissions permits a good idea. Resour. Futur., Issues Brief 2, 1–10.
Rausch, S., Metcalf, G.E., Reilly, J.M., 2011. Distributional impacts of carbon pricing: a general equilibrium approach with micro-data for households. Energy Econ. 33, 20–33.
Renner, S., 2018. Poverty and distributional effects of a carbon tax in Mexico. Energy Policy 112, 98–110.
Ritchie, H., Roser, M., 2017. CO_2 and Other Greenhouse Gas Emissions. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions. (Accessed 8 December 2018).
Round, J., 2003a. Social accounting matrices and SAM-based multiplier analysis. In: Silva, L. A. P. d., Bourguignon, F. (Eds.), The Impact of Economic Policies on Poverty and Income Distribution: Evaluation Techniques and Tools. World Bank Publications, Washington, USA, pp. 301–324 (Chapter 14).
Round, J., 2003b. Constructing SAMs for development policy analysis: lessons learned and challenges ahead. Econ. Syst. Res. 15, 161–183.
Sajeewani, D., Siriwardana, M., Mcneill, J., 2015. Household distributional and revenue recycling effects of the carbon price in Australia. Clim. Change Econ. 6, 1–23.
Schwaiger, H., Tuerk, A., Pena, N., Sijm, J., Arrasto, A., Kettner, C., 2012. The future European Emission Trading Scheme and its impact on biomass use. Biomass Bioenergy 38, 102–108.
Simshauser, P., Tiernan, A., 2018. Climate change policy discontinuity and its effects on Australia's national electricity market. Aust. J. Public Adm. 1–20.
Siriwardana, M., Nong, D., 2018. Economic implications for Australia and other major emitters of trading greenhouse gas emissions internationally. Int. J. Glob. Warming 16 (3), 261–280.
Siriwardana, M., Meng, X., McNeill, J., 2013. A CGE assesment of the Australian carbon tax policy. Int. J. Glob. Energy Issues 36, 242–261.
Stern, N., Peters, S., Bakhshi, V., Bowen, A., Cameron, C., Catovsky, S., et al., 2006. Stern Review: the Economics of Climate Change, vol. 30. HM treasury London.
The Treasury, 2011. Strong Growth, Low Pollution: Modelling a Carbon Price. Commonwealth of Australia, Canberra.
Tiezzi, S., 2005. The welfare effects and the distributive impact of carbon taxation on Italian households. Energy Policy 33 (12), 1597–1612.
Truong, T.P., Kemfert, C., Burniaux, J.M., 2007. GTAP-E: an Energy-Environmental Version of the GTAP Model with Emission trading, DIW-Diskussionspapiere. No. 668, 2007.
Villoria-Saez, P., Tam, V.W., del Río Merino, M., Arrebola, C.V., Wang, X., 2016. Effectiveness of greenhouse-gas Emission Trading Schemes implementation: a review on legislations. J. Clean. Prod. 127, 49–58.
Weitzman, M.L., 1974. Prices vs. Quantities. Rev. Econ. Stud. 41, 477–491.
World Energy Statistics, 2018. Global Energy Statistical Yearbook 2018. https://yearbook.enerdata.net/total-energy/world-energy-production.html. (Accessed 8 December 2018).